File Code: 3400
Date: July 18, 2007

Randy Turner
Superintendent
USDI National Park Service
Morristown National Historic Park
30 Washington Place
Morristown, NJ 07960-4299

Dear Mr. Turner:

Enclosed is a biological evaluation on two hemlock pest at Morristown National Historic Park. A total of five areas were evaluated in March 2007 including: Cross Estates, behind the Cross Estates, Indian Graves Brook, Reynolds Property and the Warren Property.

In brief, majority of the hemlocks surveyed at Morristown NHP appear to be relatively healthy except for the Reynolds Property of which the hemlock trees appear to be in moderate decline.

Hemlock woolly adelgid (HWA) and elongate hemlock scale (EHS) are present at all the surveyed areas. HWA and EHS populations are variable, and range from low to heavy densities among trees. The native *Abgrallaspis ithacae* (hemlock scale), and the exotic *Nuculaspis tsugae* circular scale were also present but are of lesser concern since EHS usually out competes these scales. Impacts to hemlock resources at Morristown NHP are expected unless management actions are implemented.

Because all hemlock trees are accessible by truck and have populations of both adelgid and scales, our recommendation is to apply a 2 % solution of horticultural oil using a hydraulic sprayer capable of saturating the entire crown of the trees. Treatment timing should coincide with peak EHS crawler emergence in early summer and repeated in the fall if new scale or HWA appear on the 2007 new growth.

Please contact Brad Onken (304)-285-1546 or Karen Felton (304)-285-1556, if you have any questions concerning this report.

Sincerely,

Bob Lueckel

Robert Lueckel
Field Representative MFO

Enclosure

Cc: Bob Mason, Morristown NHP
Wayne Millington, USDI NPS, IPM
George Koeck, NJDA
Jerry Boughton, AO

Biological Evaluation of Hemlock Health At Morristown National Historical Park, Morristown, New Jersey July, 2007

Prepared by

Karen Felton, Biologist
And
Bradley Onken, Entomologist
USDA Forest Service
State and Private Forestry
Forest Health Protection
180 Canfield Street
Morgantown, WV 26505

(Onken and Souto 2006). In New Jersey twelve years after initial HWA infestations, tree mortality reached more than 90% in some hemlock stands (Mayer et al 2002).

The hemlock woolly adelgid is parthenogenetic (an all-female population with asexual reproduction) that has six stages of development: the egg, four nymphal instars, and the adult, and two generations a year on hemlock. The winter generation, the sistens, develops from early summer to midspring of the following year (June-March). The spring generation, the progrediens, develops from spring to early summer (March-June). The generations overlap in mid to late spring.

The hemlock woolly adelgid is unusual in that it enters a period of dormancy during the hot summer months. Prior to dormancy, the nymphs produce a tiny halo of wool-like wax filaments surrounding their bodies. The adelgids begin to feed once cooler temperatures prevail, usually in October and continue throughout the winter months. As it matures this woolly covering increases in size and becomes more conspicuous. This woolly sac (ovisac) helps protect the insect and its eggs from natural enemies and prevents them from drying out. These ovisacs can be readily observed from late fall to early summer on the underside of the outermost branch tips of hemlock trees.

Figure 1. Hemlock woolly adelgid nymphs in dormancy.

Figure 2. Hemlock woolly adelgid ovisacs (woolly sac).

The ovisacs of the winter generation contain up to 300 eggs, while the spring generation ovisacs contain between 20 and 75 eggs. The hemlock woolly adelgid also has a winged form that is produced by the spring generation. This form must complete part of its life cycle on spruce. The apparent lack of a suitable spruce host for this form in eastern North America results in a substantial loss of adelgids each year (McClure 1992b). Although natural mortality in HWA populations is commonly between 30 to 60 percent (McClure 1989, 1996), the reproduction potential of this insect remains high. Other mortality is generally attributed to two likely causes: 1) an extended period of cold temperatures or rapid temperature changes that coincides with a susceptible period of development for the adelgid, and/or 2) a sufficient loss in the nutritional quality and quantity of the food source, which is associated with the decline in health and vigor of the host tree (McClure 1996, Onken et al. 1999).

ithacae, is native to the United States and is probably present throughout the East. *A. ithacae* is generally not a significant pest (Johnson and Lyon 1988). The hemlock scale has also been reported on fir (*Abies* species) and spruce (*Picea* species) (Drooz 1989). Two exotic scales that attack the eastern and Carolina hemlock are the elongate hemlock scale, *Fiorinia externa*, and the shortneedle evergreen scale (a circular hemlock scale), *Nuculaspis tsugae* (Johnson and Lyon 1988, McClure 2002a). Native to Japan, the shortneedle evergreen scale and the elongate hemlock scale were first reported in the United States, in 1910 and 1908, respectively. The shortneedle evergreen scale is now known to occur in Connecticut, Maryland, New Jersey, Rhode Island, and New York (McClure 2002a), and its hosts other than hemlock include fir, cedar (*Cedrus* species), spruce and yew (*Taxus* species) (Drooz 1989). The EHS has been found in the District of Columbia and in nine states from Virginia to southern New England and west to Ohio (McClure 2002b). The EHS is known to occur on species of spruce, fir, yew and hemlock (Drooz 1989). Spruce and fir tend to be even more susceptible than hemlock, although it has not yet spread into the natural ranges of these other native conifers. Circular hemlock scale is far less abundant and generally out competed by the elongate hemlock scale (McClure 2002a).

The EHS completes two generations each year in the Southern and Mid-Atlantic States, but usually only one in the Northeast. Its life stages are broadly overlapping everywhere, and crawlers can be found throughout the spring and summer. Crawlers are the only stage capable of dispersing and establishing new infestations. Dispersal between trees is primarily by wind and birds. Females have three stages of development after the egg stage, while males have five. During the first and second instar stages, both sexes settle beneath the thin waxy cuticle on the lower surface of the youngest hemlock needles and begin to feed. While in these stages, both sexes secrete a cover around itself as it grows. Adult female covers are elongate and translucent light yellow to brown in color, and approximately 2mm long. The male cover is elongate, white and about 1.5mm long. After the first and second nymphal instar stages, the female then molts into the adult feeding stage, while the male molts into a non-feeding prepupa and spins a cocoon, where it pupates before it emerges as an adult. The adult male mates with the female and dies soon thereafter without feeding. The adult female lays about 20 eggs within her cover. The EHS usually overwinters, either as an egg or as an inseminated adult female. When the crawlers hatch, they exit through a small opening at the posterior end of the cover (McClure 2002b).


Figure 3. Elongate hemlock scale on the lower surface of hemlock needles.

The EHS attacks the underside of the hemlock needles by removing fluids from the mesophyll cells through piercing and sucking mouthparts. Scale populations build slowly on healthy trees, but much more quickly on stressed ones. Feeding by HWA has been shown to affect nutrient dynamics in hemlock stands (Jenkins et al. 1999) and this could feasibly reduce tree vigor sufficiently to allow scale insects such as EHS to become established and explode in

METHODS

Twenty one hemlock trees lining the driveway to the Cross Estates, three behind the Cross Estates mansion, two at Indian Grave Brook, three at the Reynolds Property, and seven at the Warren Property were included in this survey. An assessment of tree vigor, branch tip dieback, new shoot growth, DBH (estimated tree diameter at breast height to nearest inch), and HWA and EHS population densities was conducted of each tree.

Figure 4. Collecting branch samples at Reynolds Property, March 2007.

A GPS (global positioning system) unit was used to collect coordinates (decimal degrees, WGS84) and map the area surveyed within the park. A GPS point represents the general area of each plot.

At each sample tree, up to four branch samples (measuring 30 centimeters in length) were selected from the lower crown from different sides of the tree. The number of branch samples per tree varied based on the availability of branches that could be reached. On each branch, HWA densities were designated as heavy, moderate, light or none based on the percentage of tips with adelgid present and categorized as follows:

Heavy (H) = >50% infested
Moderate (M) = 25% to 50% infested
Light (L) = <25% infested
None (N) = 0% infested

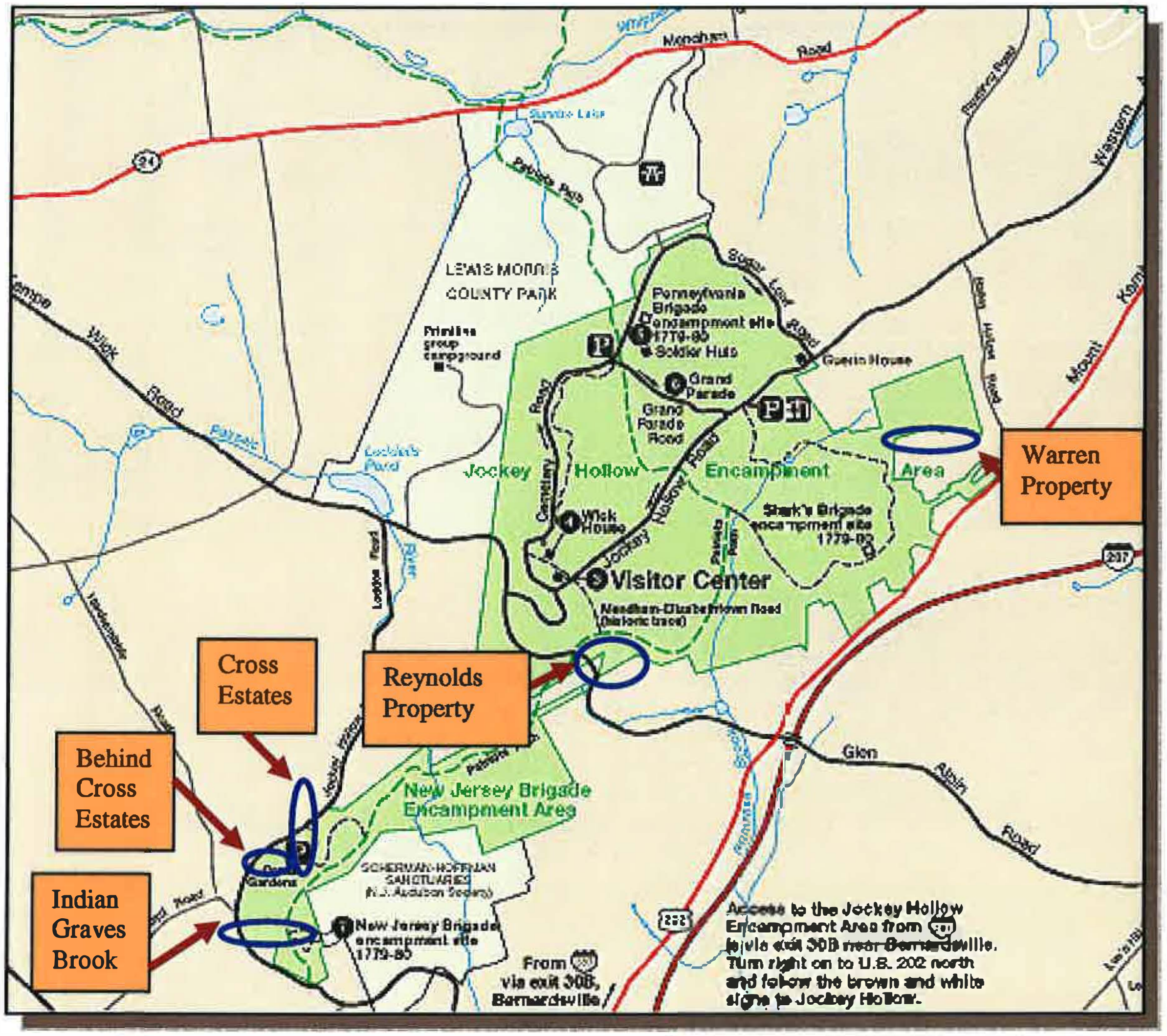
EHS density estimates were designated as heavy, moderate, light or none based on the criteria below:

Heavy (H)= >1/needle on average
Moderate (M) = 1/needle on average
Light (L)= <1/needle on average
None (N)= 0% infested

Following the pest density estimates, the relative abundance of new growth and shoot tip dieback was determined by assessing each tip within the 30 centimeters of branch length. The results were then divided by the total number of tips on each branch sample.

Average winter HWA mortalities were low at Morristown NHP (range = 11%-62%). The highest average, 62%, was recorded at the Warren property but this is not considered significant.

Figure 6. Hemlock woolly adelgid and elongate hemlock scale survey locations at Morristown National Historic Park – March, 2007.



DISCUSSION

The majority of hemlocks surveyed at Morristown NHP appear to be in relatively good health, except for hemlocks at the Reynolds property which appeared to be stressed. This is evident in the higher HWA and EHS population densities, and the moderate vigor ratings and lower percentages of new tip growth.

The native hemlock scale, *Abgrallaspis ithacae*, and the exotic *Nuculaspis tsugae* circular scale were present on a number of trees. *N. tsugae* occurred in higher densities than *A. ithacae*. Both of these scales are usually out competed by the EHS.

HWA and EHS densities are variable among trees and are present at all the survey locations. Consequently, impacts to the hemlock resources at Morristown NHP are expected to occur, unless some type of management action is taken.

Management Considerations

Chemical management options for protecting hemlock stands are limited by the biology and feeding behavior of HWA, pest population densities, site conditions (i.e. proximity to streams), accessibility and limited application technology currently available. Insecticide treatments although effective, are conducted on an individual tree basis which can be both labor intensive and costly. Thus treatment strategies are typically focused in high value sites such as recreational or scenic areas or where hemlock stands have an important ecological role or genetic preservation is a high priority. Classical biological controls such as predators and pathogens are being pursued by the USDA Forest Service but will likely take years to become effectively established. As such, preservation of hemlocks in the short term will require intensive monitoring and periodic chemical treatments when infestations are discovered.

Foliar chemical treatments. Aerial spray using horticultural oil or insecticidal soap is not an option because aerial sprays could not provide the needed "saturation" necessary to ensure that the insecticide adequately covers the insect. Aerial spraying with more toxic insecticides (e.g. malathion or diazinon) would have very significant, unacceptable impacts on a wide range of non-target insects and other animals and limited control benefits (Evans 2000). Application of insecticides using ground spraying equipment is generally limited to areas accessible to hydraulic spray equipment and areas where over spray or run off would not contaminate streams, lakes or ponds. Backpack sprayers could be effectively used for foliar treatment of infested seedlings and saplings to protect regeneration.

Systemic Insecticides. Several systemic insecticides are labeled for adelgids and can be injected (e.g. imidacloprid, bidrin or Metasystox-R®) or implanted (e.g. acephate) into hemlock trees. Imidacloprid is by far the most common systemic insecticide being used to control HWA and is applied as a soil drench or injected into to the soil around hemlock

imidacloprid-treated trees should be carefully monitored for increases in mite populations.

Little is known about the biotransformation and bioactivity of the metabolites of imidacloprid in hemlock. What is known is that trunk-injected imidacloprid generally requires a week or longer to provide adelgid control, with protection lasting for up to 2 years (Tater et al. 1998, Silcox 2002). The soil injection or soil drench methods of imidacloprid treatments can take several months for translocation to occur but typically has provided better consistency in treatment efficacy and is expected to provide control for at least 3 years. Stem injections should not be used on severely stressed trees.

***Biological control*:** There are no known parasites of adelgids. There are three predatory beetles approved for release and each is unique in its dispersal, reproductive potential, feeding behavior, and suitable climate regimes. They are all very host specific. Where these natural enemies are released is the responsibility of state forest health specialists from each state and the USFS. All of the releases are in infested hemlock stands found primarily along the leading edge of the generally infested area, where hemlocks are still healthy and HWA densities have not yet overwhelmed the trees. The release and establishment of HWA natural enemies is not likely to provide short term control of HWA. It is considered to be a long term approach and will likely require a complex of natural enemies to maintain HWA below damaging levels. It may be years before these predators can self perpetuate sufficiently before any level of success can be determined.

The first predator beetle to be imported and released for biological control is a tiny, black lady beetle, *Sasajiscymnus tsugae*, from Japan. Since 1995, over 1.5 million *S. tsugae* beetles have been released in over 200 sites in 16 eastern states from Georgia to Maine. The recovery of *S. tsugae* beetles in the years following releases have been sporadic, and rarely have there been more than one or two beetles recovered per site. Adult beetles have been captured near some of the release sites more than 6 years after release, and some more than 1/2 a mile from nearest release site.

Figure 13. Beetles released for biocontrol (left to right): *Sasjiscymnus tsugae* from Japan, *Scymnus sinuanodulus* from China and *Laricobius nigrinus* from Pacific Northwest.

Another predatory beetle, *Scymnus sinuanodulus*, a lady beetle from China, has been released since 2005. More than 16,000 adult beetles have been released in eight states. So far, few beetles have been recovered from the release sites.

A Derodontid beetle, *Laricobius nigrinus*, from the Pacific Northwest is also approved for release. Mass rearing of this predatory beetle began in 2003, and more than 30,000 beetles have been released in eleven states. Recovery of *L. nigrinus* has been confirmed at most sites. At some release sites, adult beetles are easily found and hundreds of larvae have been recovered.

the HWA. As a best management practice, the USFS has previously recommended that hemlocks within 50 feet of open water be treated with a stem injection rather than a soil treatment. Research at the CT Agricultural Research Station has recently demonstrated that imidacloprid binds tightly with organic soils such that movement more than a few centimeters is unlikely when the chemical is placed in the organic layer of the soil. Imidacloprid will leech through mineral soils quite readily and it is critical applicators use good judgment as to placement of the injector tip in organic soils which in most cases, is less than 3 inches deep. This depth also coincides with the shallow feeder roots of eastern hemlock. With this new research information, soil treatments closer to open water may be acceptable when treatment decisions are based on the soil conditions surrounding each tree to be treated within the 50 foot buffer. In circumstances where rocky porous soils exist or the organic layer in not sufficiently deep enough to handle the injector tip placement, trees should be treated using a stem injection system.

Release of predatory beetles is not a feasible recommendation since there are no hemlock stands large enough to establish self perpetuating populations.

There has been some evidence that nitrogen fertilizers can enhance the fecundity of both HWA and EHS, so it is important not to apply nitrogen fertilizers near trees until these pests have been eliminated.

Resource managers should continue to annually monitor tree health conditions, scale and adelgid population densities and treatment efficacy.

Doccola, J.J. P.M. Wild, I. Ramasamy, P. Castillo, and C. Taylor. 2003. Efficacy of arborjet viper microinjections in the management of hemlock woolly adelgid. Journal of Arboriculture. 29(6): 327-330.

Drooz, A.T. 1989. Insects of eastern forests. USDA, Forest Service. Micellaneous Publication No. 1426. 608 p.

Evans, R.A. 2000. Draft Environmental Assessment: for the Release and Establishment of *Pseudoscymnus tsugae* (Coleoptera: Coccinellidae) as a Biological Control Agent for Hemlock Woolly Adelgid (*Adelges tsugae*) at the Delaware Water Gap National Recreation Area. USDI, National Park Service, Northeastern Region. 23 p.

Felsot, A. 2001. Admiring Risk Reduction: Does Imidacloprid have what it takes? Agrichemical and Environmental News 186: 2-13.

Godman, R.M. and K. Lancaster. 1990. *Tsuga canadensis* (l.) Carr., eastern hemlock. In: R.M. Burns and B.H. Honkala, eds. Silvics of North America, vol.1, conifers. USDA Forest Service, Agriculture Handbook No. 654. pp. 604-612.

Helms, J.A., ed. 1998. The dictionary of forestry. The Society of American Foresters. Bethesda, MD.

Hennessey, R.D. and M.S. McClure. 1995. Field release of a non-indigenous lady beetle, *Pseudoscymnus* sp. (Coleoptera: Coccinellidae), for biological control of hemlock woolly adelgid, *Adelges tsugae* (Homoptera: Adelgidae). Environmental Assessment prepared by USDA, Animal and Plant Health Inspection Service, Riverdale, MD. Unpub. Report. 6 p.

Hepting, G.H. 1971. Diseases of forest and shade trees of the United States. USDA Forest Service, Agricultural Handbook 386. 488-491.

James, D.G. and T.S. Price. 2002. Imidacloprid boosts TSSM egg production. Agrichemical and Environmental News 189: 1-11.

Jenkins, J.C., J.D. Aber, and C.D. Canham. 1999. Hemlock woolly adelgid impacts on community structure and N cycling rates in eastern hemlock forests. *Canadian Journal of Forest Research* 29: 630-645.

Johnson, W.T. and H.H. Lyon. 1988. Insects that Feed On Trees and Shrubs. 2nd Ed. Cornell University Press, Ithaca, N.Y. 102-105 p.

Lapin, B. 1994. The Impact of Hemlock Woolly Adelgid on Resource in the Lower Connecticut Valley. USDA. Northeastern Center for Forest Health research, Hamden, CT. 45p.

McClure, M.S. and C.A.S-J. Cheah. 2002. Establishing Pseudoscymnus tsugae Sasaji and McClure (Coleoptera:Coccinellidae) for the biological control of the hemlock woolly adelgid, Adelges tsugae, Annand (Homoptera:Adelgidae), in the Eastern United States. In: Onken, B., R. Reardon, and J. Lashomb (Eds.), Proceedings, Symposium on the hemlock woolly adelgid In Eastern North America, February 5-7, 2002, East Brunswick, NJ. N.J. Agricultural Experiment Station Rutgers. 351-352 p.

McClure, M.S., S.M. Salom, and K.S. Shields. 2001. Hemlock woolly adelgid. USDA, Forest Service, Forest Health Technology Enterprise Team, Morgantown, WV, FHTET-2001-03. 14 p.

Montgomery, M.E. 1999. Woolly adelgids in the southern Appalachians: Why they are harmful and prospects for control. In: Gibson, P. and C. Parker, (Eds.), Proceedings of the Appalachian biological control initiative workshop. USDA, Forest Service, Forest Health Technology Enterprise Team, Morgantown, WV, FHTET-98-14. 59 p.

Montgomery, M.E. and S.M. Lyons. 1996. Natural enemies of adelgids in North America: Their prospect for biological control of *Adelges tsugae* (Homoptera: Adelgidae). In: Salom, S.M., T.C. Tigner, and R.C. Reardon, (Eds.), Proceedings, First hemlock woolly adelgid review, 12 October, 1995, Charlottesville, VA. USDA, Forest Service, Forest Health Technology Enterprise Team, Morgantown, WV, FHTET-96-10: 89-102.

Mullins, J.W. 1993. Imidacloprid: a new nitroguanidien insecticide. In: Duke, S.O., J.J. Menn, and J.R. Plimmer (eds.), Pest control with enhanced environmental safety. American Chemical Society Symposium, ASC, Washington DC: 183-189.

Onken, B., D. Souto, and R. Rhea. 1999. Environmental Assessment for the release and establishment of *Pseudosymnus tsugae* (Coleoptera: Coccinellidae) as a biological control agent for the hemlock woolly adelgid. USDA, Forest Service, Morgantown, WV.

Quimby, J. 1996. Value and importance of hemlock ecosystems in the eastern United States. In: S>M> Salom, T.C. Tigner, and R.C. Reardon, eds. Proceedings of the First Hemlock Woolly Adelgid Review, Charlottsville, VA, 1995. USDA Forest Service, Forest Health Technology Enterprise Team-Morgantown, WV. FHTET 96-10. pp1-8.

Rhea, J.R. 1996. Preliminary results for the chemical control of hemlock woolly adelgid in ornamental and natural settings. In: Salom, S.M., T.C. Tigner, and R.C. Reardon, (Eds.), Proceedings, First hemlock woolly adelgid review, 12 October, 1995, Charlottesville, VA. USDA, Forest Service, Forest Health Technology Enterprise Team, Morgantown, WV, FHTET-96-10: 89-102.

Webb, R.E., J.R. Frank, and M. J. Raupp. 2003. Eastern hemlock recovery form hemlock woolly adelgid damage following Imidacloprid therapy. Journal of Arboriculture. 29(5): 298-302.

Yamasaki, M., R.M. DeGraaf, and J.W. Lanier. 2000. Wildlife habitat associations in eastern hemlock – birds, smaller mammals, and forest carnivores. In: Proceedings of a Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America, edited by K.A. McManus, K.S.Shields, and S.R.Souto. pp.135-141.

Young, J.A., D.R. Smith, C.D. Snyder, and D. P. Lemarie. 1998. A landscape-based sampling design to assess biodiversity losses from eastern hemlock decline.